3.1 FLIGHT PATH

To examine the effect of TSPI errors on RADGUNS outputs, the standoff jammer ECM option was used to simulate positioning of a decoy at various offsets from the target aircraft. The decoy was positioned directly in front and back of, to the right and left of, and above and below the target centroid as shown in Figure 3.1-1. The distances shown in the figure are in meters and are denoted as positive or negative using the same axis convention as defined in the *RADGUNS User Manual*. The target aircraft was flown at two offsets from the X axis along a linear flight path, while a decoy with an RCS of approximately 10 times the target RCS was flown at a constant offset from the target aircraft. This forced the simulated gun system to track and shoot at the decoy while calculating miss distances with respect to the target centroid. The position of the decoy was adjusted to represent typical TSPI errors (1 to 15 ft).

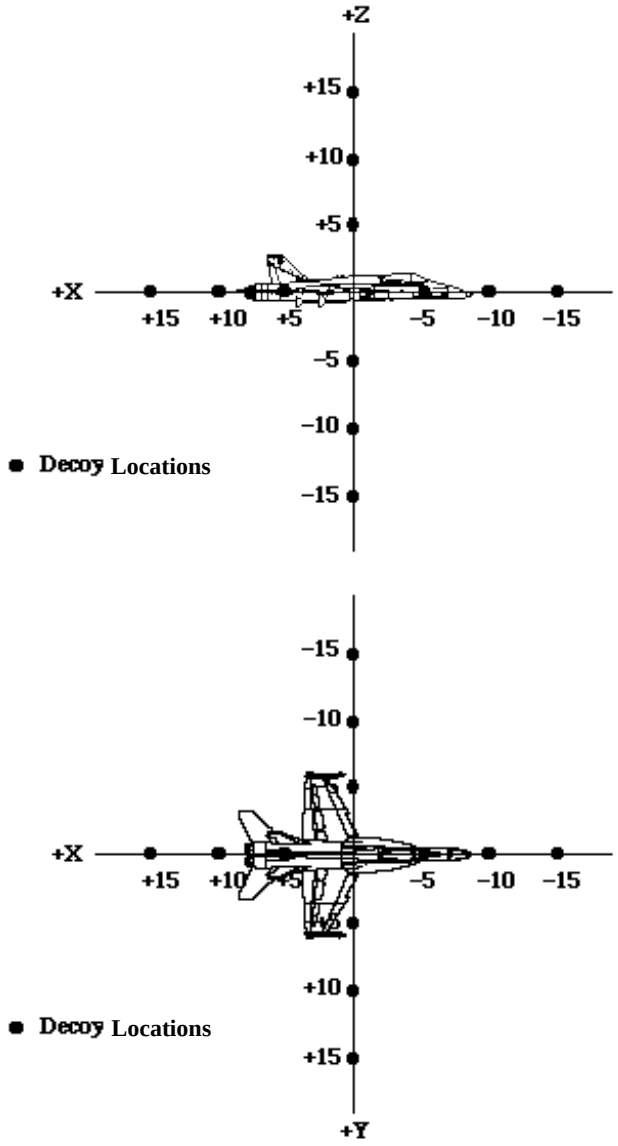

FIGURE 3.1-1. Target Aircraft and Decoy Positioning.

Tables 3.1-1 through 3.1-9 summarize the simulation results for a one square meter target aircraft at 0, 500, and 1000 meter offsets from the weapon system for a "no decoy" case, and for each of the four decoy positions shown in Figure 3.1-1. These tables include the number of rounds fired during the engagement; average and RMS miss distances (the distance from the aircraft centroid to the projectile at the closest point of approach); the cumulative probability of hit (P_h); the expected number of hits; the ratio of the number of rounds fired to the number of expected hits; and the average azimuth, elevation and range tracking errors. The decoy was first positioned 5 meters from the target in each of the six directions and then incrementally moved out 5 additional meters from the target. Due to the small size of the target aircraft, the effect of glint on tracking errors is minimized for the "no decoy" case.

TABLE 3.1-1. $1m^2$ Target at 150 m/s with 0 Offset.

Decoy Position	**Left**				**Right**		
	0	**-5y**	**-10y**	**-15y**	**+5y**	**+10y**	**+15y**
Rounds Fired	692	692	692	584	692	692	678
Average Miss Distance (m)	3.17	5.949	10.21	13.65	6.03	10.41	14.43
Cumulative P_h	0.98	0.84	0.51	0.23	0.83	0.49	0.24
Expected Hits	3.91	1.85	0.71	0.26	1.78	0.68	0.28
Rounds/Expected Hits	177	374	974	2216	388	1022	2464
Average Azimuth Error (mrad)	6.124	9.504	13.350	8.102	9.033	12.700	9.028
Average Elevation Error (mrad)	1.081	1.105	1.167	0.767	1.086	1.165	0.793
Average Range Error (m)	0.516	0.507	0.480	0.455	0.502	0.471	0.443

TABLE 3.1-2. $1m^2$ Target at 150 m/s with 0 Offset.

Decoy Position	**Forward**				**Behind**		
	0	**-5x**	**-10x**	**-15x**	**+5x**	**+10x**	**+15x**
Rounds Fired	692	693	584	574	691	646	652
Average Miss Distance (m)	3.17	2.78	1.43	2.15	3.72	2.53	3.07
Cumulative P_h	0.98	1.00	0.99	0.92	0.93	0.89	0.85
Expected Hits	3.91	6.08	4.77	2.50	2.61	2.18	1.92
Rounds/Expected Hits	177.10	114.00	122.50	229.50	264.40	296.20	340.50
Average Azimuth Error (mrad)	6.12	6.18	0.76	0.78	6.13	0.72	0.55
Average Elevation Error (mrad)	1.08	0.98	1.46	2.24	1.96	2.36	2.73
Average Range Error (m)	0.52	3.32	6.23	9.66	2.35	5.48	9.01

TABLE 3.1-3. $1m^2$ Target at 150 m/s with 0 Offset.

Decoy Position	Below				Above		
	0	**-5z**	**-10z**	**-15z**	**+5z**	**+10z**	**+15z**
Rounds Fired	692	692	692	644	692	662	674
Average Miss Distance (m)	3.17	7.10	11.47	15.16	5.56	8.21	13.05
Cumulative P_h	0.98	0.76	0.43	0.21	0.99	0.58	0.84
Expected Hits	3.91	1.41	0.57	0.24	4.98	0.86	1.73
Rounds/Expected Hits	177	489	1218	2728	139	774	389
Average Azimuth Error (mrad)	6.12	6.11	6.23	0.66	6.18	0.86	1.38
Average Elevation Error (mrad)	1.08	3.77	6.69	8.96	2.21	5.01	7.54
Average Range Error (m)	0.52	0.75	1.18	1.56	0.50	0.69	1.17

TABLE 3.1-4. $1m^2$ Target at 150 m/s with 500 m Offset.

Decoy Position	Forward				Behind		
	0	**-5x**	**-10x**	**-15x**	**+5x**	**+10x**	**+15x**
Rounds Fired	824	824	824	824	824	824	824
Average Miss Distance (m)	2.04	2.92	5.16	7.50	2.75	4.24	6.48
Cumulative P_h	0.99	0.99	0.92	0.81	0.98	0.95	0.88
Expected Hits	5.12	4.38	2.58	1.64	4.08	3.09	2.14
Rounds/Expected Hits	161	188	319	503	202	267	385
Average Azimuth Error (mrad)	0.83	1.56	3.00	4.53	1.78	3.34	4.96
Average Elevation Error (mrad)	0.43	0.44	0.66	0.95	0.72	1.05	1.40
Average Range Error (m)	0.47	3.06	5.73	8.86	2.17	4.98	8.26

TABLE 3.1-5. $1m^2$ Target at 150 m/s with 500 m Offset.

Decoy Position	Left				Right		
	0	**-5y**	**-10y**	**-15y**	**+5y**	**+10y**	**+15y**
Rounds Fired	824	824	824	824	824	824	824
Average Miss Distance (m)	2.04	5.65	9.63	13.77	3.37	6.61	10.38
Cumulative P_h	0.99	0.93	0.64	0.31	1.00	0.99	0.90
Expected Hits	5.12	2.64	1.01	0.37	6.11	4.55	2.32
Rounds/Expected Hits	161	312	818	2208	135	181	355
Average Azimuth Error (mrad)	0.83	2.82	4.97	7.22	1.47	3.51	5.67
Average Elevation Error (mrad)	0.43	0.71	1.07	1.46	0.55	0.89	1.26
Average Range Error (m)	0.47	1.09	2.06	3.25	0.73	1.64	2.72

TABLE 3.1-6. $1m^2$ Target at 150 m/s with 500 m Offset.

Decoy Position	Below				Above		
	0	**-5z**	**-10z**	**-15z**	**+5z**	**+10z**	**+15z**
Rounds Fired	824	824	824	824	824	824	824
Average Miss Distance (m)	2.04	5.27	9.64	14.37	5.11	9.43	14.11
Cumulative P_h	0.99	0.97	0.61	0.28	0.94	0.65	0.32
Expected Hits	5.12	3.46	0.95	0.32	2.74	1.04	0.38
Rounds/Expected Hits	161	239	868	2548	301	792	2145
Average Azimuth Error (mrad)	0.83	0.82	0.83	0.83	0.82	0.81	0.81
Average Elevation Error (mrad)	0.43	2.76	5.52	8.42	2.60	5.36	8.21
Average Range Error (m)	0.47	0.62	0.94	1.43	0.47	0.69	1.18

TABLE 3.1-7. $1m^2$ Target at 150 m/s with 1000 m Offset.

Decoy Position	Left				Right		
	0	**-5y**	**-10y**	**-15y**	**+5y**	**+10y**	**+15y**
Rounds Fired	764	764	764	764	764	764	764
Average Miss Distance (m)	1.19	3.90	6.99	10.17	3.19	5.77	8.69
Cumulative P_h	0.95	0.94	0.88	0.77	0.95	0.92	0.86
Expected Hits	3.06	2.74	2.13	1.46	2.96	2.53	1.94
Rounds/Expected Hits	250	279	359	525	258	303	394
Average Azimuth Error (mrad)	0.53	1.88	3.28	4.71	1.00	2.38	3.77
Average Elevation Error (mrad)	0.38	0.49	0.64	0.81	0.41	0.54	0.72
Average Range Error (m)	0.40	1.62	3.06	4.68	1.24	2.68	4.26

TABLE 3.1-8. $1m^2$ Target at 150 m/s with 1000 m Offset.

Decoy Position	Forward				Behind		
	0	**-5x**	**-10x**	**-15x**	**+5x**	**+10x**	**+15x**
Rounds Fired	764	764	764	764	764	764	764
Average Miss Distance (m)	1.19	4.01	7.12	10.35	2.47	5.48	8.71
Cumulative P_h	0.95	0.91	0.77	0.60	0.94	0.86	0.68
Expected Hits	3.06	2.36	1.48	0.93	2.87	1.96	1.15
Rounds/Expected Hits	250	324	515	826	266	391	664
Average Azimuth Error (mrad)	0.53	1.27	2.51	3.88	1.68	3.05	4.49
Average Elevation Error (mrad)	0.38	0.27	0.25	0.34	0.52	0.67	0.83
Average Range Error (m)	0.40	2.77	5.18	7.93	2.01	4.53	7.39

TABLE 3.1-9. $1m^2$ Target at 150 m/s with 1000 m Offset.

Decoy Position	Below				Above		
	0	**-5z**	**-10z**	**-15z**	**+5z**	**+10z**	**+15z**
Rounds Fired	764	764	764	764	764	764	764
Average Miss Distance (m)	1.19	4.71	9.14	13.90	4.97	9.45	14.21
Cumulative P_h	0.95	0.92	0.73	0.39	0.90	0.70	0.37
Expected Hits	3.06	2.53	1.33	0.49	2.34	1.19	0.46
Rounds/Expected Hits	250	302	576	1564	326	643	1658
Average Azimuth Error (mrad)	0.53	0.52	0.52	0.53	0.52	0.52	0.52
Average Elevation Error (mrad)	0.38	2.17	4.25	6.43	2.00	4.08	6.25
Average Range Error (m)	0.40	0.53	0.77	1.08	0.39	0.50	0.78

Figures 3.1-2 through 3.1-7 show average errors for azimuth (mrad), elevation (mrad), and range (meters) as well as average miss distance (meters) as a function of decoy position for the in-bound and out-bound segments of the zero offset passes. The X coordinate represents decoy placement in meters from the target centroid in accordance with Figure 3.1-1. The Y coordinate gives the error as indicated in the chart legend.

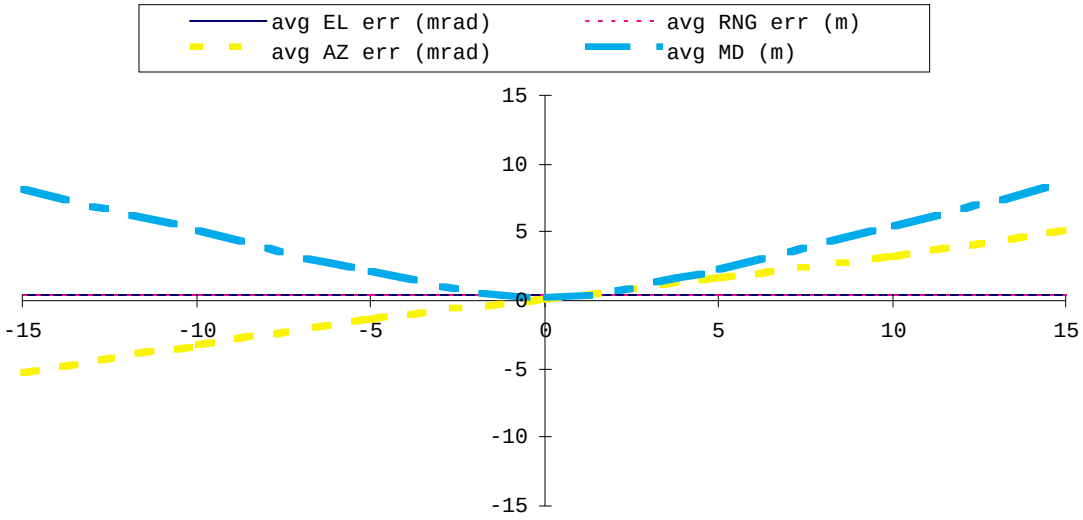

FIGURE 3.1-2. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target In-bound, Decoy to Left/Right.

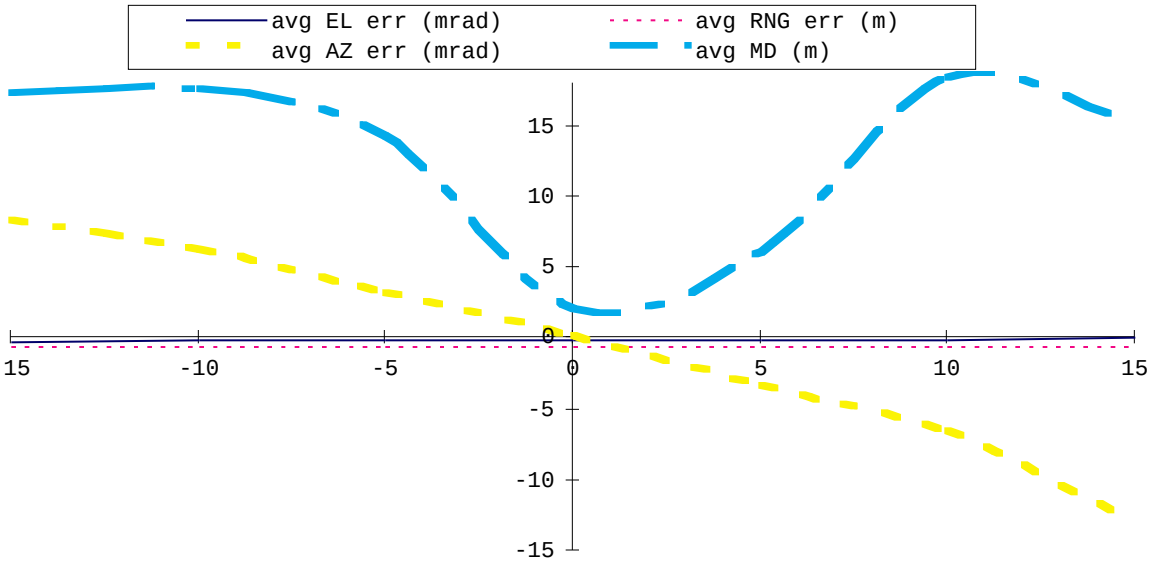

FIGURE 3.1-3. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target Out-bound, Decoy to Left/Right.

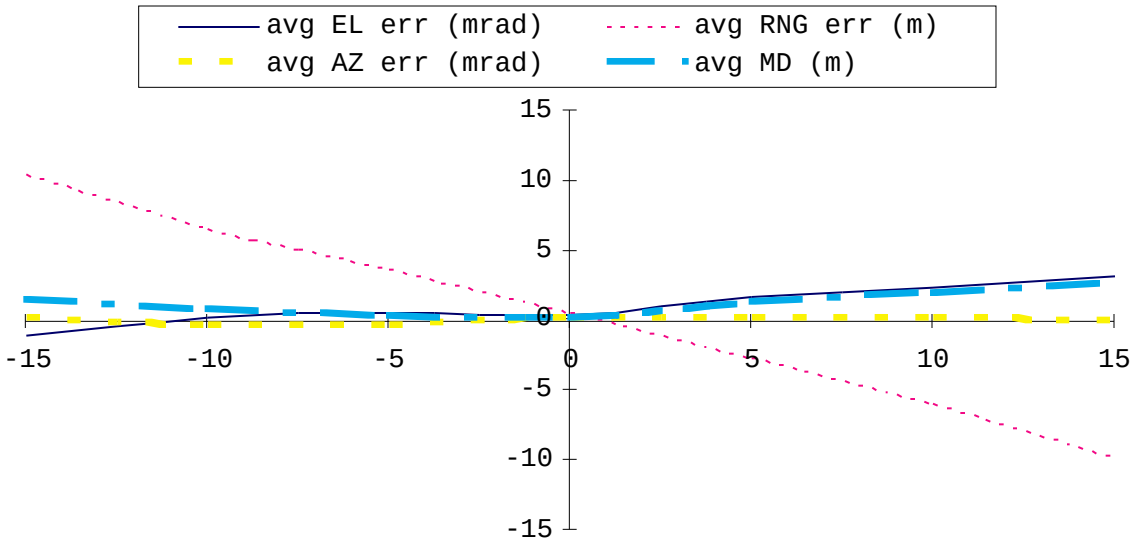

FIGURE 3.1-4. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target In-bound, Decoy Front/Behind.

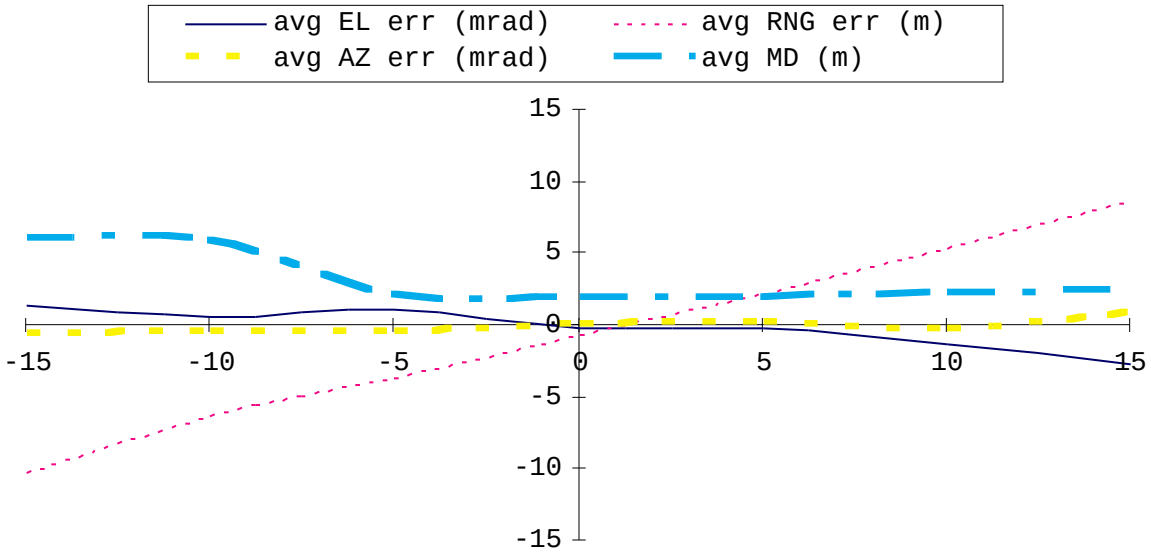

FIGURE 3.1-5. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target Out-bound, Decoy Front/Behind.

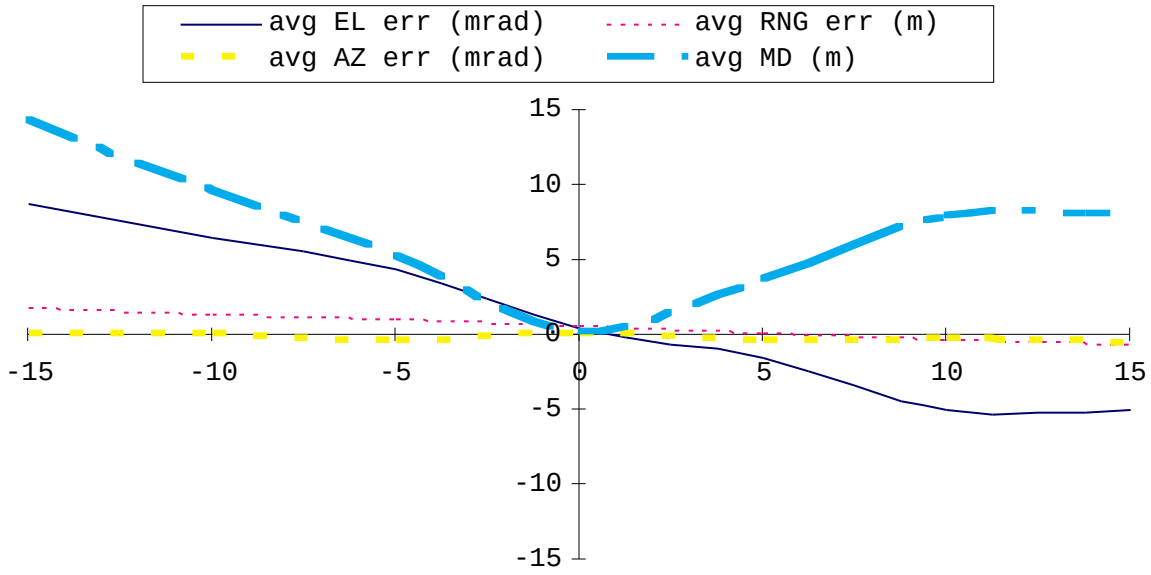

FIGURE 3.1-6. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target In-bound, Decoy Below/Above.

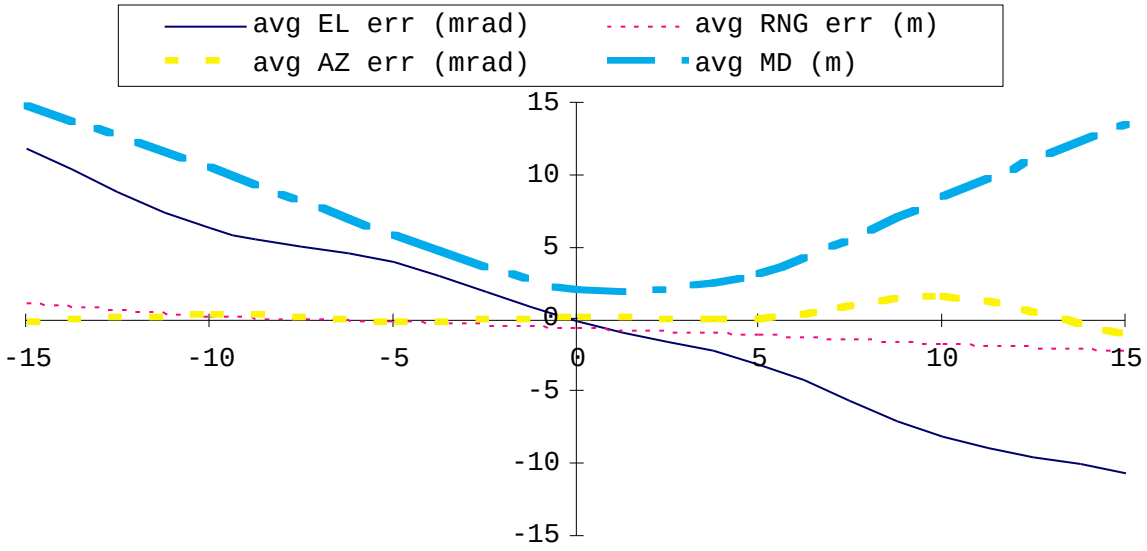

FIGURE 3.1-7. Average Tracking Errors and Miss Distance vs. Decoy Offset, Target Out-bound, Decoy Below/Above.

Figures 3.1-8 through 3.1-10 show the effect of decoy position on probability of hit for each of the offsets. For the 0 offset case (where there is no change in azimuth), the drop in P_h is almost linear with the distance left or right that the gun is forced to shoot at. A similar trend exists when the gun is forced to shoot below the target, but when the guns are superelevated slightly (less than 5 m), there is an increase in P_h.

For the 500 m offset, P_h decreases as the aimpoint below or above the aircraft increases. A similar trend is seen when the guns shoot at a point to the left of the target centroid. Shooting at some point to the right of the target has very little impact as that point is essential masked by the aircraft. Although P_h falls as the guns are aimed farther in front of or behind the aircraft, the effect of leading or lagging the aircraft is minimal.

For the 1 km offset case, the elevation aim point most significantly affects P_h, followed by the lead angle, and to a much lesser extent, the aimpoint component to the left or right of the target centroid.

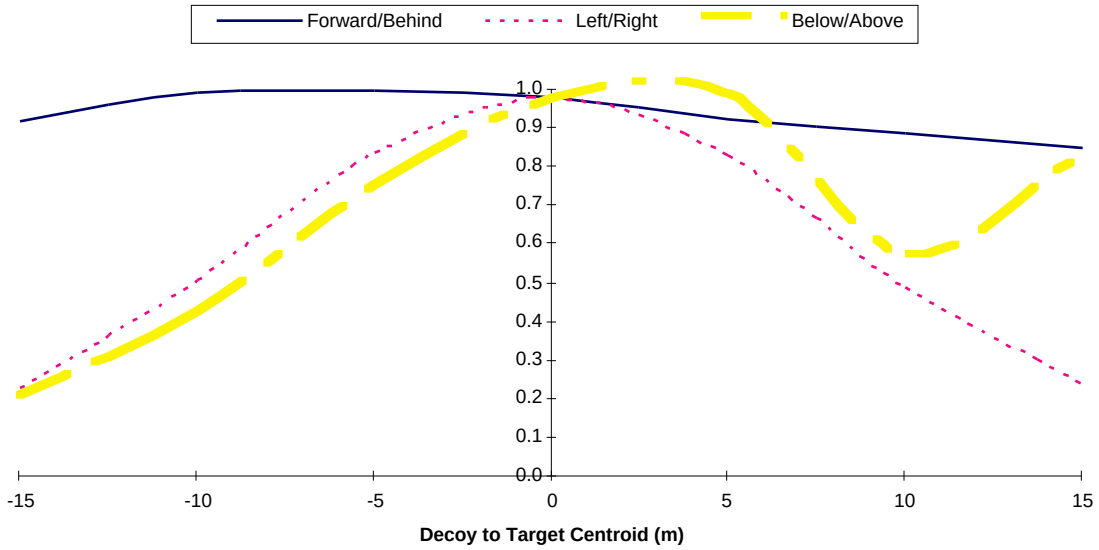

FIGURE 3.1-8. P_h as a Function of Decoy Position (0 m Offset).

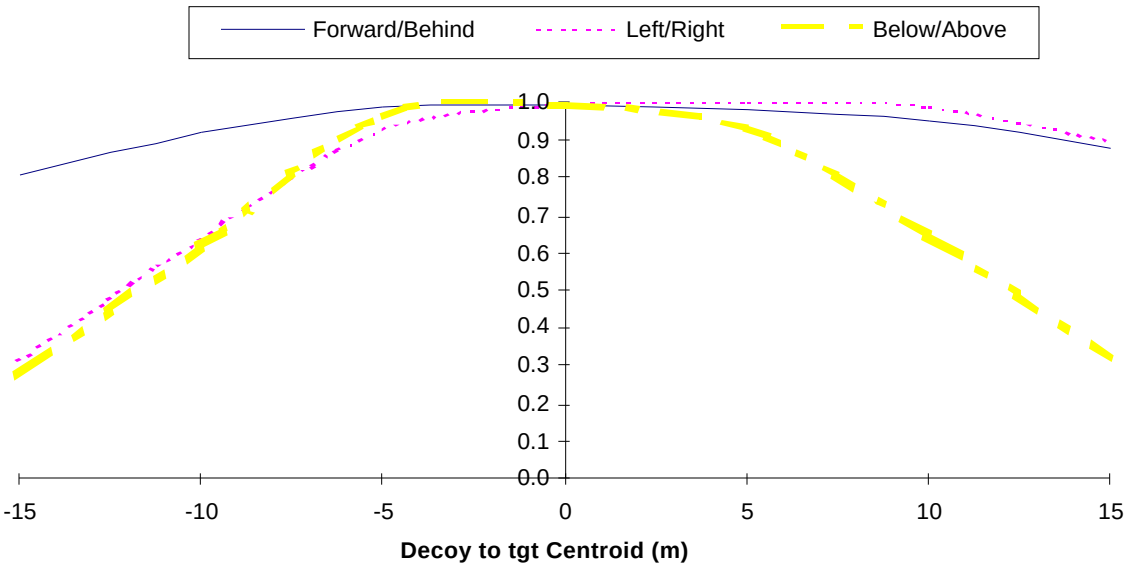

FIGURE 3.1-9. P_h as a Function of Decoy Position (500 m Offset).

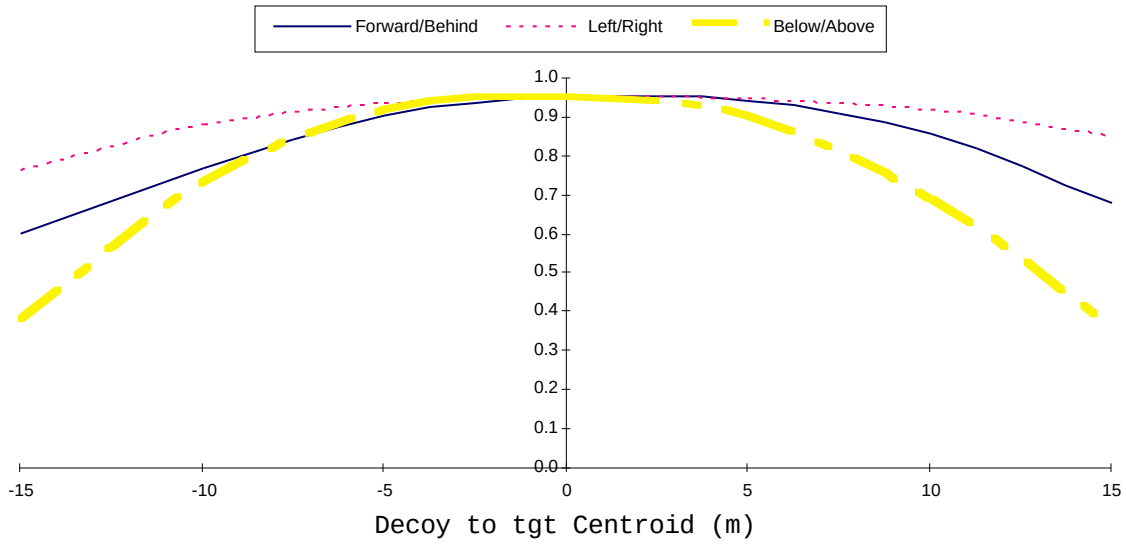

FIGURE 3.1-10. P_h vs Decoy Position (1 km Offset).

3.1.1 Conclusions

As expected, for straight and level passes, positional errors are, for the most part, linearly related to tracking errors, where an error in the right/left plane leads to azimuth errors, an error in the forward/rear plane leads to range errors, and an error in the vertical plane leads to elevation errors for the 0 offset case. The effect of positional errors on higher level MOEs such as probability of hit varies with the geometry of the engagement, but for the cases shown, P_h can be either increased or decreased due to positional error. In all cases examined, probability of hit is most sensitive to positioning the vertical plane. For the zero offset case, forcing the system to track and engage 15 m below the target leads to a 77% reduction in P_h. While it is highly unlikely that a well calibrated system would consistently track with errors on the order of 15 m over the duration of an engagement, positional errors can significantly impact prediction of tracking errors and probability of hit for specific time segments and geometries.